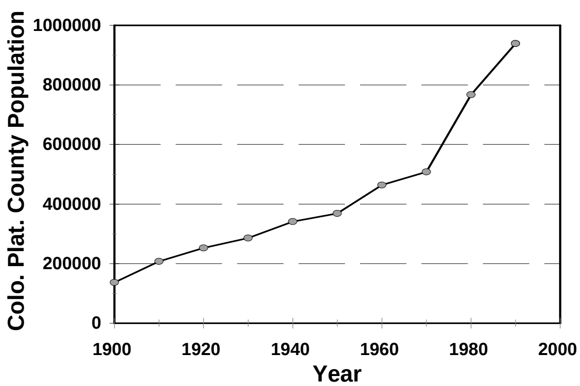
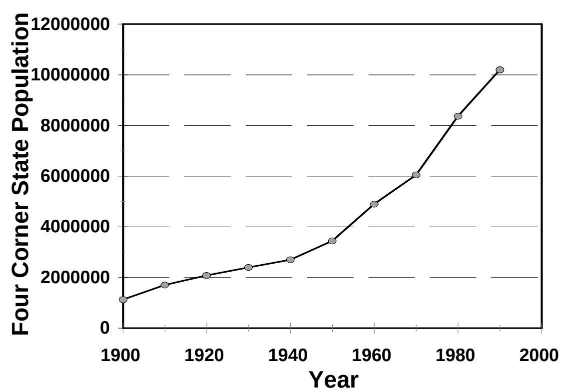
Chapter 14. Colorado Plateau Summary and Recommendations

Changes in the Colorado Plateau

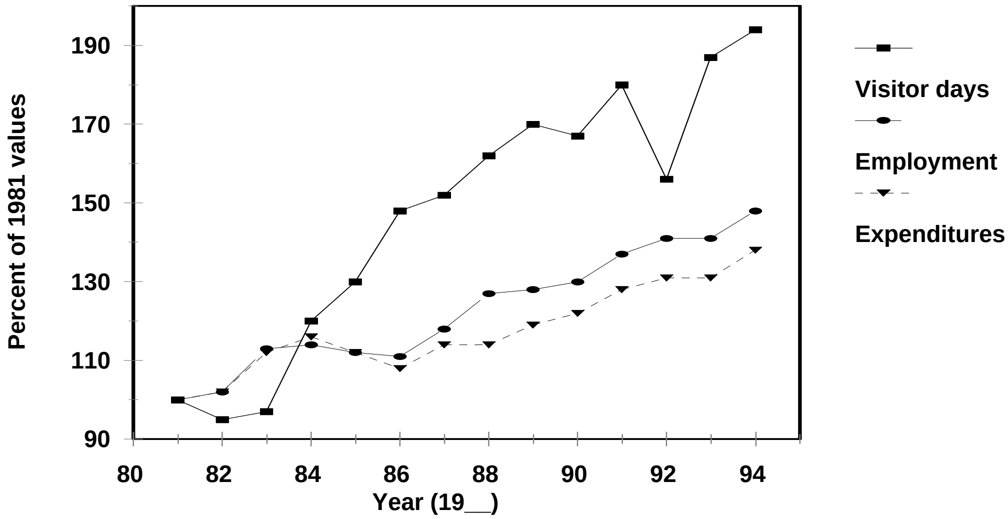
Almost all aspects of the Colorado Plateau are experiencing substantial change. Human populations are increasing rapidly on the Colorado Plateau and in the Four-Corners states (Figures 14-1, 14-2). Visitation at the Grand Canyon is expected to reach 6 million visitors per year in the near future (GCVTC 1996). The vegetation in the National Parks and Monuments of the Colorado Plateau is currently undergoing substantial changes from a variety of causes. Fire suppression over the past 80 yrs has led to unusual accumulation of fuels, and to "outbreaks" of trees with forests replacing forest/grassland mixtures (Covington and Moore 1994). Many areas are also





experiencing reduced or eliminated grazing by cattle. Prescribed fire programs in some Parks (such as Bryce Canyon) are designed to return vegetation to more natural composition and structure.

The growth in local and regional populations has been accompanied by very large increases in visitation to the National Park units of the Colorado Plateau (Figure 14-3). Visitation almost doubled between 1981 and 1994, from 8.7 million visitor days in 1981 to 16.7 million visitor days (Hecox and Ack 1995). The number of National Park Service employees increased at less than half of this rate, and expenditures (in constant 1981 dollars) lagged even further behind.



Visibility

The protection of Air Quality Related Values (AQRVs) in the NPS Class I areas of the Colorado Plateau occurs in the context of many changes. Emissions of S compounds have generally declined around the region, but emissions of NO_x compounds may remain constant and then increase in the next century (GCVTC 1996). Much of the increase in the next century will come from vehicle emissions, both within the region and from large population centers such as Phoenix, Salt Lake City, Las Vegas, and Los Angeles.

The major documented changes on AQRVs will be related to visibility. The Grand Canyon Visibility Transport Commission (GCVTC 1996) projected that visibility would improve for a few years, and decline again because reduced source emissions would be offset by an increase in sources as a result of economic activity and population. Natural production of aerosols in wildland fires has probably been abnormally low for several decades, but projected increases in prescribed fire and perhaps wildfire will periodically reduce visibility on the Plateau.

Reductions in visibility from sulfate may be marginally alleviated, depending on the degree to which emissions of SO_2 are reduced from existing sources or increased by additions of new point sources. Given that low-visibility days are due in large part to high concentrations of sulfate aerosols, any increase or decrease in S emissions should directly affect visibility. As identified by the GCVTC, there is an inability to differentiate local (Las Vegas, Nevada; Salt Lake City, Utah; Phoenix, Arizona) and regional sources of air pollution and their effects on visibility. Therefore, future studies could be focused on this issue.

Air Pollutant Impacts on Vegetation

We found no evidence of any impact of current air quality conditions on other AQRVs such as vegetation or stream chemistry.

Ambient concentrations of SO_2 are far below thresholds for impacts on sensitive plants. Ozone concentrations are relatively low on an average basis, but moderate ozone exposures occur at certain periods in several of the Parks and Monuments. No evidence of any impacts (such as foliar injury or abnormal growth or mortality) has been reported. In general, the current levels of ozone are probably too low to affect the conifers, but may be high enough to affect aspen (and closely related cottonwoods?). Most shrubs, herbs, and grasses on the Plateau have never been screened for sensitivity to ozone.

Sensitivity of Soils and Surface Waters to Acidification

In general, surface waters and watersheds of the Colorado Plateau are resistant to chemical change due to low levels of acidic deposition and to the nature of the region's hydrogeology. Some of the park units discussed in this review have some regions that are characterized by bedrock resistant to weathering (e.g. Great Sand Dunes National Monument). Small pools, ponds, and streams found on more crystalline rock may be susceptible to change due to atmospheric inputs. A potentially important data gap is the potential for aquatic system change due to nitrogen inputs to both the aquatic and terrestrial ecosystems of the Colorado Plateau.

The EPA recently issued a report that attempted to answer the question: "what acidic deposition levels are necessary to protect sensitive regions?" This study examined critical loads from the perspective of setting a standard that might have any one of the following environmental goals: a) maintenance of specific conditions as observed at a particular point in time, b) return to pre-industrial conditions, or c) a level that balances effects, costs, and other societal values (EPA 1995). The current pH of rainfall in the Plateau is not low enough to cause any direct acidification problems. Wet deposition of N is very low (about 1 kg N ha^{-1} yr^{-1} across the Plateau), and it is unlikely that such low rates could increase N availability enough to substantially alter any plant communities. A range of “critical loads” cannot be determined at this point because high ANC in water bodies and low rates of deposition have not allowed any impacts to be discerned. We conclude that current rates of deposition probably exceed pre-industrial conditions (b above), but that no impacts on AQRVs are apparent (a above). The NADP monitoring data show significant declines in S deposition at some sites on the Plateau, and no trends in N deposition. Our present finding of no impact on AQRVs from deposition of S and N may not hold if deposition rates increase substantially; research that included experimental treatments with realistic rates of S and N addition would be needed to form a basis for establishing critical loads.

Recommendations

Visibility is the major known AQRV affected by current air quality on the Colorado Plateau. Human-related emissions contribute most of the visibility impairment when visibility is poorest. The IMPROVE protocols are sufficient for gauging patterns in visibility, and in identifying the compounds responsible for visibility impairment. Our synthesis showed that visibility differs among the Parks and Monuments of the Plateau. Therefore, air quality at one location cannot in general be extrapolated simply from other sites because of differences in major sources of pollution, distances from sources, and weather patterns. In addition, the Grand Canyon Visibility Transport Commission (GCVTC 1996) stressed that local sources of pollution may substantially impair visibility when low-wind weather systems dominate.

<u>Recommendation #1</u>: Visibility is an important AQRV of the Colorado Plateau. Present visibility on the Plateau is impaired by pollution and would be sensitive to changes in pollutant concentrations. The data collected from IMPROVE Protocol monitoring provide a means to establish present conditions and estimate spatial and temporal trends. These data also form the basis of analyses that can, in a general way, identify source regions responsible for impairment. Additional monitoring for specific units and resources for special studies may be desirable, and more work is needed to identify the contribution of specific point sources and of urban centers (particularly Las Vegas and urban centers in California) to visibility impairment.

The National Park Service has a policy and obligation to develop baseline inventories of the natural resources protected within the National Parks and Monuments (Stohlgren et al. 1995). Most parks have incomplete species lists, only partial geographic information on location of species and communities, and few have any monitoring program that would identify moderate changes in the state of health of ecosystems. The Inventory and Monitoring Program of the NPS aims to achieve these goals (Ruggiero et al. 1992).

Recommendation #2: Substantial changes in vegetation are likely to develop in the coming decades, as a result of natural succession processes, fire regimes (including suppression, prescribed fire, and wildfire), responses to grazing (or cessation of grazing), visitor impacts, impacts of changing wildlife populations, and from driving forces such as pollution and climate change. The role of pollution in these changes can only be determined by adequate characterization of the nature and extent of changes, coupled with experimental information to determine the likely causes of the changes. Therefore, we recommend that broad-based resource monitoring in the Parks and Monuments be given a high priority.

- A reconnaissance survey of all Class I NPS areas is needed to determine if foliar injury from ozone is occurring. Ozone concentrations in some Parks and Monuments are high enough that injury is plausible, but none has been reported. The lack of injury reports could indicate no effects, or a lack of a thorough reconnaissance by experts who can identify foliar injury. A single late-summer expedition would provide a foundation for determining the extent of any current problem and whether follow up surveys (in more depth) are warranted. This reconnaissance-level survey could be repeated after any summer with notably high ozone concentrations. Other surveys may be useful in the future if unexpectedly large changes in air quality develop. These might include monitoring changes in the extent of lichen cover on rocks.

Recommendation #3: Monitoring of effects of deposition (both wet and dry) on surface waters needs to be continued or expanded. No estimates of rates of dry deposition are currently available for the Colorado Plateau, so an attempt should be made to estimate dry deposition rates using both the National Dry Deposition Network (NDDN) data and particle concentration data collected as part of the IMPROVE network. This work would need to examine and improve the algorithms that are currently used to translate ambient concentrations of dry species to deposition loadings.

- Too little is known about the biogeochemistry of small ponds and rock pools to know if increasing deposition of N (or S) could alter these unique ecosystems. Therefore, biological properties and pH, ANC, sulfate-S, ammonium-N, and nitrate-N should be monitored, particularly for water bodies with ANC < 200 μeq/L and those on resistant bedrock (such as quartzite). Sulfur isotope analysis of waters could be used to estimate the contribution of different sources of sulfur (e.g. power plants, smelters) to increased acidity and sulfate in these freshwaters. A number of parks are involved in cooperative projects with the USGS-Water Resources Division as part of the National Water Quality Assessment Program (NAWQA). We recommend that the park staff review the surface water chemistry data with USGS researchers periodically to identify waters that might be sensitive to changes due to deposition.

- An experimental focus is needed on the episodic change in chemistry of sensitive water during large events. Sensitive systems are most likely to show changes in chemistry and biota following large rain storms that flush accumulated dry deposition in small pools and streams. Where appropriate, rainfall events could be monitored, and short term responses in stream or pool chemistry could be studied (using automatic sampling devices). Before reaching conclusions about the effect of chemical changes on biota, controlled dose/response experiments would be needed (using native vertebrate and invertebrate species). In conducting these experiments it is important to determine the range of natural variability in both the chemistry of these systems and the biological response to changes in both hydrology and chemistry.

As mentioned above, a key challenge in any ecological monitoring program is deducing the processes that generated any changes that were observed over time. If aspen declines as a component of the forests on the North Rim of the Grand Canyon, would it be likely that ozone played a role? A variety of experiments are needed to determine the likely sensitivity of Colorado Plateau species and ecosystems to air quality.

Recommendation #4: A series of strategic experiments should be developed to address the likely impact of reasonable exposures to air pollutants and deposition.

- A wide range of plant species needs to be screened in controlled fumigation experiments for sensitivity to ozone (in the range of 40 to 60 ppb average, with peak exposures of 100-120 ppb). These fumigations need to include manipulations of water supply (for at least a subset of the species) to examine the effects of moisture stress on reducing the ozone impacts on the plants. Another possible approach for examining potential impacts of current ozone levels would be testing plants on-site in charcoal-filtered air; open top chambers could be placed around established plants with and without filtered air treatments. Any increased growth in the filtered chambers would be consistent with an ozone-induced effect on growth.

- The pollutant of most concern relative to setting of critical loads is N because of the likely increase in the emissions of nitrogen oxides and ammonia due to human activities. Experimental additions of N are needed to a wide variety of ecosystems (from grasslands, shrublands and forests to potholes and streams) to provide a basis for insights about critical loads of N deposition in the Colorado Plateau (similar to experiments by Wedin and Tilman 1996, but with much lower application rates of < 2 g N m^{-2} yr^{-1}). When experimental manipulations within Parks are not feasible, surrounding land managed by the USFS or BLM may provide suitable "surrogate" sites. A modeling component may be an important part of projects that attempt to identify critical loads for Colorado Plateau ecosystems (both terrestrial and aquatic).

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